Heat Absorption and Release Characteristics on Heat Storage Walls with Different Materials

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Abstract: To analyze the storage performance of the envelope structure, based on the law of conservation of energy, the ANSYS software was employed to perform thermal analysis on three conventional wall materials and phase change materials, and the temperature fields and minimum temperature difference of the walls with different materials were obtained. The heat absorption and release characteristics of different wall materials were studied. Comparing the heat absorption and release characteristics of phase change materials, it was concluded that the phase change materials had better heat storage capacity, which provided a basis for promoting and developing low energy consumption technologies for buildings.

1 Introduction

According to the forecast, energy consumption can only be maintained for hundreds of years at the current rate of energy consumption, so the energy issue will become one of the challenges facing social development and even human survival. More research on building energy efficiency and improving life quality has become the focus of attention.

In recent years, a large number of studies have been carried out on heat storage walls with different materials. The effects of the thermal performance of the wall and the thickness of the wall on the heat flux time lag and heat flux decrement factor were studied by Jin et al. [1]. Kong et al. [2] investigated the dynamic heat transfer performance through the external wall with aerogel insulating layer under different outside temperatures. The impact of composite phase change material thermal properties on the thermal performance was studied by using two-dimensional enthalpy model [3]. Pan et al. [4] used the orthogonal analysis method to optimize the index values of the building envelope capacity through energy consumption simulations. Bastien and Athienitis [5] designed the thermal energy storage systems to maximize their impact on reducing indoor temperature diurnal swings.

Therefore, this paper used ANSYS software to investigate thermal performance on three conventional materials and paraffin-like phase change material. The absorption and exothermic properties of paraffin phase change materials and convectional materials were analysed and compared to accelerate the process of building low energy consumption.

2 Simulation details

2.1 Methods

ANSYS software was employed to model and analyse heat storage performance on the different material. Before carrying out the simulations, the following assumptions were made.

(1) Effects of speed changes and surface tension changes due to a phase change of the phase change material were ignored.

(2) Local thermal equipment was maintained between fluid and solid regions.

(3) Thermal property parameters of all the materials were constant, i.e., they did not change with temperature.

2.2 Model and boundary conditions

In this work, a simple 4-layer composite wall with different materials was built, in which they were defined as the outer insulation layer, the plastering layer, the main layer and the inner insulation layer, respectively. The thickness of the four layers in composite wall were 60 mm, 20 mm, 220 mm and 20 mm in order. The established model and meshing were shown in Fig. 1. Since the continuity equations and the energy equation used in the simulations were in common, they were not repeated.

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Fig. 1. Calculation model and meshing.

In the model, the first and fourth layers as outer and inner insulation of the wall body used the same material of the insulation type expanded vitrified microbeads lightweight mortar. For comparative analysis, the main layer materials were used by sintered fly-ash concrete, aerated concrete, red brick block and paraffin, respectively. The thermal properties of all the materials were listed in Table 1-3.

Table 1. Thermal properties of ordinary heat storage materials

Materials	Thermal property parameters			Remark
	Density kg/m ³	Heat conductivity coefficient W/m·K	Specific heat capacity J/g·K	
Sintered fly-ash concrete	1500	0.70	1050	Main layer
Aerated concrete (B07)	700	0.29	1050	
Red brick block	1800	0.81	1050	
Cement plaster	1800	0.93	1050	Plastering layer
Insulation type expanded vitrified microbeads lightweight mortar	300	0.07	1468	Insulation layer

Table 2. Thermal properties of composite phase change material

Materials	Thermal property parameters		
	Density kg/m ³	Heat conductivity coefficient W/m·K	Specific heat capacity J/g·K
Paraffin (Main layer)	920	0.22	2000
Cement mortar (Plastering layer)	1800	0.93	1050
Insulation type expanded vitrified microbeads lightweight mortar (Insulation layer)	300	0.07	1468

Table 3. Phase change enthalpy of composite phase change material

Temperature/°C	0	10	22	30	36
Enthalpy value/kJ/m ³	0	24014.2	52831.2	74042.6	96355.3

The boundary conditions settings were shown in Table 4. In the control equations, h is the convective heat transfer coefficient, which can be calculated by the following empirical formula.

$$h = 11.6 + 7 \times w^{0.5}$$

where, w is the wind speed. As different wind speed values were determined, convective heat transfer coefficients of indoors and outdoors could be obtained.

Table 4. Boundary Condition Setting

Locations	Boundary Conditions
$X = 0$	$-\lambda_1(\partial T/\partial n)_{w1} = h_1(T_{w1} - T_{f1})$
$X = X_4$	$-\lambda_2(\partial T/\partial n)_{w2} = h_2(T_{w1} - T_{f1})$
$Y = 0, Y = Y_1$	$-\lambda(\partial T/\partial n)_w = 0$

2.3 Outdoor temperature setting

According to the summer temperature in Hefei, we choose the day of July 20 as the basis. Based on the tested outdoor temperature, we process the data using the method of the least squares and get the equation of the outdoor temperature as follows,

$$T_{\text{outwall}} = -8.17086 \times 10^{-28} t^6 + 3.2129 \times 10^{-22} t^5 - 4.23169 \times 10^{-17} t^4 + 2.21975 \times 10^{-12} t^3 - 3.69214 \times 10^{-8} t^2 - 4.78448 \times 10^{-5} t + 27.45905$$

where, t is a certain time of day. The results are shown in Fig. 2.

Fig. 2. Outdoor temperature.

3 Results and discussion

3.1 Thermal characteristics of conventional heat storage walls

We simulated the thermal characteristics and obtained the temperature fields of three materials at four moments of 10000 s, 20000 s, 30000 s and 40000 s. The simulation results were shown in Fig. 3. From the results, from left to right are the temperature fields of sintered fly-ash concrete, aerated concrete and red brick block respectively in every moment.

Fig. 3. Temperature fields of three conventional materials

In addition, calculated by heat transfer simulation, inner wall temperatures of three conventional materials were obtained. The results were shown in Fig. 4. According to the comparison and analysis of the simulation results, we could find that when the temperature fluctuation is gentle from 0 to 40000 s, and the minimum inner wall temperature difference of the aerated concrete is about 5, which highlights the role of aerated concrete as a wall material to improve the indoor temperature fluctuation. It is suggested that the aerated concrete was recommended for the main structure to better store the incoming indoor heat and effectively prevent heat loss.

Fig. 4. Inner wall temperature of different conventional materials

3.2 Thermal characteristics of phase change heat storage wall

Using this phase change wall as the control group of aerated concrete wall, other simulation conditions were

consistent with the above conventional materials. Fig. 5 presented the results of temperature fields of phase change material at different moments with 10000s, 20000s, 30000s and 40000s respectively.

Fig. 5. Temperature fields of phase change material

3.3 Comparative analysis

According to the above analysis, the numerical results of the internal wall temperature of the phase change material and the aerated concrete material were compared and analysed, as shown in Fig. 7.

Fig. 6. Comparison on thermal performance of phase change material and aerated concrete.

From Fig. 6, it was found that indoor temperatures of both phase change and aerated concrete materials increased with the time from 0 to 32000 s around due to heat generated by the absorb sunlight. When the time was from 32000 s to 40000 s, the outdoor sunlight became weaker, that is, the indoor heat source gradually disappeared, and the indoor temperature decreases to 16 °C, with a decrease of about 2.5 °C. Noting that when the outdoor temperature decreased, the phase change wall could store the indoor heat, which reflected the good heat storage performance. So, the indoor temperature of the phase change material wall is 8 °C lower than that of the convectional wall. The quality of indoor thermal environment has a significant impact on heating energy consumption. For regions with hot summer and cold winter, the reduction of 1 °C in winter will reduce building energy consumption by about 10 %. It can effectively regulate the indoor day and night temperature and thus improve the living environment and energy efficiency.

4 Conclusions

In this work, the thermal characteristics of three conventional materials and phase change material were

simulated by using ANSYS software. Temperature fields and the minimum temperature difference of the inner wall of each wall material were obtained. And through comparative analysis on the inner wall temperatures between the phase change material and aerated concrete, it could be concluded that the temperature inside the wall with phase change materials fluctuates gently, with a decrease of about 2.5°C. It indicated that the application of phase change material could obviously improve the heat storage capacity and delay the change of temperature.

Acknowledgement

Foundation item: National Key Research and Development Project of China (No. 2017YFC0702600) and Foundation of Anhui Province Key laboratory of Intelligent Building and Building Energy Saving (No. IBES2018KF06)

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